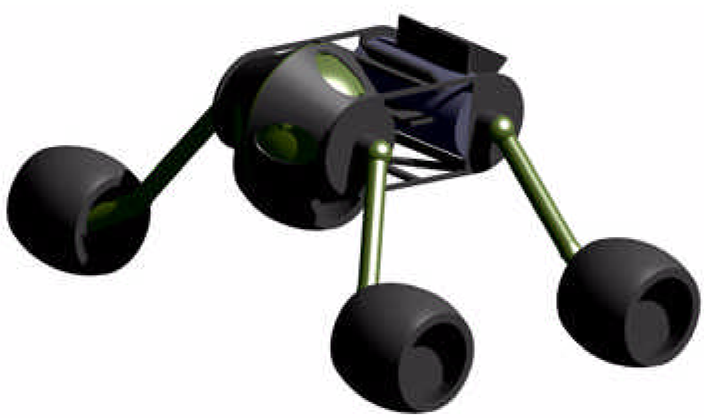
Stirling Cooler Designed for Venus Exploration



Artist's conception of a robotic rover for the exploration of Venus, incorporating a spherical electronics enclosure and a Stirling cooler for heat rejection (CAD visualization by Shawn A. Krizan of Analytical Mechanics Associates, Inc.).
The figure shows a four-wheeled rover, with a spherical thermal enclosure in the front and a power supply and heat pump at the rear, with fins to reject heat to the Venus atmosphere.

Venus having an average surface temperature of 460 °C (about 860 °F) and an atmosphere 150 times denser than the Earth's atmosphere, designing a robot to merely survive on the surface to do planetary exploration is an extremely difficult task. This temperature is hundreds of degrees higher than the maximum operating temperature of currently existing microcontrollers, electronic devices, and circuit boards.

To meet the challenge of Venus exploration, researchers at the NASA Glenn Research Center studied methods to keep a pressurized electronics package cooled, so that the operating temperature within the electronics enclosure would be cool enough for electronics to run, to allow a mission to operate on the surface of Venus for extended periods.

In the Venus electronics package design, the electronics are located inside a 25-cm-diameter spherical thermal enclosure. The design uses a Stirling engine to serve as a heat pump to eject heat through a heat pipe away from the interior of the thermal enclosure. The cold side of the heat pipe (inside the thermal enclosure) is at 473 K (200 °C). This temperature was chosen so that a currently available high-temperature silicon-based microcontroller could operate. The Stirling cooler transfers the waste heat to convective radiators, which efficiently reject heat to the Venus atmosphere at a temperature of 500 °C, 40 °C above the surface ambient temperature.

The cooling requirement to keep the heat pipe cold-side temperature at 475 K is 105 W of heat pumping. As calculated using the Stirling heat-engine design tool SAGE, the configuration that was modeled effectively pumps 100 W of heat across the required 300 °C of temperature differential with an operating coefficient of performance of 0.44, requiring approximately 240 W of input power, which can be provided by an isotope power system. The cooler operates with a working fluid of 46 bar nomi-nal pressure (4.6 MPa) of gaseous helium. The estimated mass of the cooler is 1.6 kg.

Because this new heat pump design keeps the thermal enclosure at a moderate temperature, it is now possible to plan missions to explore the most hostile environment in our Solar System: the surface of Venus. With some modifications, the electronics cooling system design may be able to be adapted to other missions, such as near-Sun missions, Mercury surface robots, and volcano exploration.

Find out more about this research: http://rasc.larc.nasa.gov/
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